A PRELIMINARY REVIEW OF IRRIGATION CONTROL FOR SITE-SPECIFIC MICROIRRIGATION

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SUMMARY: A recent development in irrigated crop management is the concept of precision irrigation. The objective of precision irrigation is to manage spatial and temporal variability in crop yields by applying water precisely in each management zone or to individual plants. To implement this approach it is necessary to both accurately assess the spatial water demand of the crop as well precisely control the required water application. This paper provides a preliminary review of irrigation controller technology, specifically in relation to applications for site-specific management of micro-irrigation systems.

KEYWORDS: irrigation; precision; automation; control; technology.

RESUMO: Um desenvolvimento recente no manejo de culturas irrigadas é o conceito de irrigação de precisão. O objetivo da irrigação de precisão é gerenciar a variabilidade espacial e temporal das colheitas através da aplicação de água com precisão em cada área do talhão ou para plantas individuais. Para implementar esta abordagem é necessário tanto avaliar com precisão a demanda de água espacial da cultura, assim como controlar a demanda temporal de água. Este artigo fornece uma revisão preliminar da tecnologia de controladores de irrigação, especificamente voltados para a gestão de sistemas de micro-irrigação.

PALAVRAS-CHAVE: irrigação; precisão; automação; controle; tecnologia.

INTRODUÇÃO

Precision agriculture (PA) is a concept and management model which has great potential to enhance the sustainability of the agricultural sector. The main principle is that the application of crop inputs can be optimised by taking into account the spatial variability that exists within the fields. In general, PA provides the opportunity to reduce the amount of input (e.g. fertiliser, water, pesticides) applied per total unit area, with a reduction in input costs and an increase in profitability compared to traditional models of management which treat the crop

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uniformly. There may also be environmental benefits arising from better targeting the application of inputs using PA approaches.

One of the first commercial PA technologies involved the application of dry granular fertilizer (Wollenhaupt and Buchholz, 1993). Since that time, other inputs (e.g. pesticides and liquid nutrients) have also been spatially managed using PA technology. However, according to Sadler et al. (2000) water is a key crop production input in irrigated crops that should be managed on according PA concepts. A range of factors could be expected to vary spatially within an irrigated crop field influencing both the crop water demand (e.g. plant genetics, disease) and soil water availability (e.g. texture, soil water holding capacity, drainage). Variability in crop water requirements and demand has been shown by remotely sensed images of plant canopy temperature showing spatially variable water stress. In addition, climate studies have shown that water availability is a major limiting factor (due to the dependence of yield on water applied) that varies temporally. Under these conditions, uniform irrigation management of large fields could produce zones within the field of over- or under-irrigation resulting in the potential for application inefficiencies, surface run-off, leaching of soil nutrients and sub-optimal yields. From these observations, Sadler et al. (2000) concluded that site-specific irrigation using PA principles would be beneficial.

Micro-irrigation (e.g. drip or micro-sprinkler) systems are generally well suited to the application of site-specific irrigation due to the pipe layout and infrastructure for water distribution within fields. Micro-irrigation enables targeted water applications to plant root zones and can also be used to apply nutrients through fertigation (e.g. Sadler et al. 2005). However, site-specific micro-irrigation requires decisions regarding when and how much water to apply according to the water requirements of individual plants or management zones. Management zones are generally areas within the field which display low heterogeneity in key production factors and hence may be managed with uniform applications of inputs. Although interest in precision irrigation has been increasing, only limited research demonstrating spatially variable irrigation applications has been published (e.g. Torre Neto et al., 2000, Miranda et al., 2005, Coates et al. 2006a; Coates et al., 2006b). The main barriers to adoption of site-specific irrigation include the lack of decision support systems, real-time monitoring and feedback to irrigation control (Sadler et al., 2005), lack of skilled labor, low cost of input water and the high cost of the available technology (Evans and King, 2010).

Research is required to demonstrate that precision irrigation is able to optimise the application of water and nutrient inputs, and is both technically and economically feasible. However, the development of low cost controllers for site-specific micro-irrigation would seem essential for this technology to become economically feasible. Hence, the aim of this paper was to review the current status of irrigation control with a specific focus on controllers for site-specific micro-irrigation.

**IRRIGATION CONTROL SYSTEMS**

A controller is a device or component that acts on a process, based on input variables that influence the output of the controlled process. In the case of irrigation systems, the irrigation control system may be required to deal with a considerable degree of complexity due to the range of factors (e.g. crop, soil, weather, application method) that influence water application
management. However, the actual irrigation management decision can be simplified to the optimal time to begin and switch off the irrigation water application. Thus, an irrigation controller is a device that controls the water application such that the appropriate quantity is applied at the right time, and in a way that optimises agricultural production and achieves high levels of water use efficiency and energy (Cornejo et al., 2005).

Clearly the performance of an irrigation control system will be a function of (a) the choice of input sensor to provide the information necessary for decision making, (b) the control logic used to make the decision, and (c) the actuators implementing the irrigation application. The control system can only perform adequately if the information passed to controller is appropriate and reliable, the associated control logic is robust, and the actuators provide accurate and precise applications.

Controllers reduce the cost of labour, facilitate irrigation operation during the night, and allow full control of irrigation with safety and practicality. These arrangements usually involve a computer system that assists in data processing (input variables), allowing efficient control of water, energy and fertilizer injection, responding to environmental changes and different stages of crop development (Zazueta and Smajstrla, 1993). The main actuators used in automated irrigation systems are typically either (a) hydraulic valves (often commanded electrically) controlling water application at either the field or plot level, or (b) supply pumps controlling water applications at the field or farm level (Souza, 2009; Pellison, 2001). The use of valves enables the control of water application within small management zones while pump control involves activation only to initiate and terminate the irrigation event at a larger scale.

SITE-SPECIFIC MICRO-IRRIGATION CONTROLLERS

Spatially variable application control systems have been developed for mobile irrigation machines such as centre pivots or linear systems (Fraisse et al., 1995, Stark and McCann 1997, King et al., 1999, Sadler et al., 2005). These machines are mechanised and have some level of automation, and hence, can be readily adapted for site-specific irrigation. However, there has been recent research into site-specific irrigation using fixed (e.g. drip) irrigation systems (Torre Neto et al., 2000, Miranda et al., 2005, Coates et al. 2004a; Coates, et al. 2006b; Delwiche et al., 2008). One of the main difficulties of implementing spatially variable irrigation management on fixed irrigation systems is that it requires a network capable of handling a large number of sensors and valves to manage the irrigation of small plot areas. For wired systems, this requires a large amount of cabling which may hinder cultivation practices and is susceptible to lightning strikes. An alternative is the use of a de-centralised (or distributed) control system that uses a stand-alone irrigation controller (possibly equipped with a solar panel) to control irrigation of each management unit and eliminating the need for wired connections between control units (King et al., 2005).

Miranda et al. (2005) developed and tested a controller for applying spatially variable irrigation water in fixed systems, using the concept of distributed control. Three matric potential sensors (Watermark sensor installed at the 0.2 m depth) were used as inputs to a controller which actuated a solenoid valve controlling water application within each management unit. When two sensors indicated that the potential was more negative than the management allowed deficit (MAD), the controller opened the solenoid valve thus started the unit irrigation. Plastic containers filled with soil and planted with Bermuda grass were used to
simulate the management zones and monitor drainage. According to the authors, the controller was effective in maintaining the root zone matric potential close to a predetermined level.

Horticultural orchards and vineyards are characterised by high costs, high risk and high economic returns, relatively lower numbers of plants per unit area (compared to broadacre crops) and commonly utilise micro-irrigation systems. Hence, these sectors are most likely to adopt site-specific micro-irrigation and irrigation controllers have been evaluated in citrus (Torre Neto et al., 2000), pistachio (Coates, 2006a) and nectarines (Coates et al., 2006b). For example, a spatially variable micro-sprinkler system was designed for citrus trees using in-field controllers (Torre Neto et al., 2000). Each crop row had two drip lines and used integrated soil moisture sensors to activate latching solenoid valves for controlling water application. Each drip line supplied a single management unit consisting of half of the trees in that row. The management units were formed by grouping trees based on size (large and small), so two drip lines per row were required. Wireless data communication between the orchard and farm office allowed remote monitoring of sensors and irrigation control in real time from the office or Internet. The entire system operated satisfactorily with the authors observing that the small trees required less water per irrigation event, but more frequent irrigation events, than the large trees.

The controllers developed by Miranda et al. (2005) and Torre Neto et al. (2000) were applied to a group of plants (i.e. the management zone). However, the size of the management unit should be a function of the environmental and crop variations but as small as possible in order to maximise the benefit of a spatially variable system. For orchards, the smallest possible management unit is the individual tree (Coates et al., 2006b) but individual sensors and outlet valves are required to manage the irrigation of an individual tree. Coates et al. (2006a) demonstrated that spatially variable irrigation management is possible by developing a spatial variable microsprinkler system consisting of four components: the microsprinkler node, drip line controller (DLC), the communication and power network, and a master computer. Fifty microsprinkler nodes were fabricated with each node consisting of a valve and an electronic circuit to individually control that valve. Using identical emitters, the amount of water applied at different locations in an orchard was adjusted by changing the duration of time that each microsprinkler valve was open. The DLC was an embedded controller designed to store irrigation schedules and control the microsprinkler nodes. The computer was in wireless communication with the DLC and provided an interface to store schedules, monitor system status, retrieve sensor data, and manually control the network. A latching solenoid valve controlled water flow at the node emitter.

**FINAL CONSIDERATIONS**

A range of irrigation control strategies and devices have been evaluated for site-specific irrigation. Most of the irrigation controllers systems developed for precision micro-irrigation rely on electronic sensors, controllers and actuation. However, the high cost, power requirements and lack of robustness of electronic systems may limit the adoption by commercial farmers, particularly for control of water applications to small plots or individual plants.
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